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EVALUATION OF THE AN/SQS-23 TR-208A TRANSDUCER (SERIAL BTD-2-69--ETC(U)
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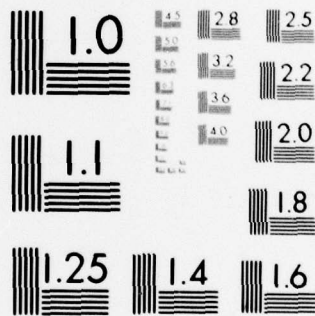
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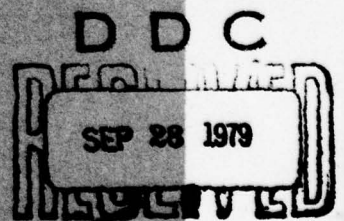
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EVALUATION OF THE AN/SQS-23 TR-208A TRANSDUCER (SERIAL BTD-2-69)

D. D. Baker
J. J. Truchard

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-69-C-1066
Proj. Ser. No. SF 11121300, Task 08048

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ABSTRACT

Applied Research Laboratories evaluated the AN/SQS-23 TR-208A transducer (serial BTD-2-69) by measurements at the Lake Travis Test Station in April 1969 and by shipboard measurements in September 1969. The principal measurements made were complex impedance (Z and ϕ) of individual transducer elements, driven individually at operating power. A conclusion drawn from this work is that impedance data measured on the bare transducer in open water compare (to within measurement accuracy) with the shipboard measurements made in the dome. This is a highly favorable indication and is a further incentive for the widespread use of element impedance measurements for transducer evaluation. In the past, such measurements have proved to be very effective at diagnosing transducer failures and impending failures.

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I. INTRODUCTION

Applied Research Laboratories conducted an evaluation of the AN/SQS-23 TR-208A transducer (serial BTD-2-69) at the Lake Travis Test Station (LTTS) during April 1969. This transducer was shipped to ARL at the request of Naval Ship Systems Command (NAVSHIPS) from the Transducer Repair Facility (TRF) at Boston Naval Shipyard. In May the transducer was reshipped to Boston where it was subsequently installed aboard the USS VOGELGESANG (DD 862). ARL personnel repeated measurements on this transducer aboard ship in September 1969. This technical memorandum contains the results of both sets of measurements on this particular transducer. ARL's data are also compared with data measured at the Boston TRF prior to shipment of the transducer to ARL. The data from Boston were forwarded to ARL at NAVSHIPS request (NAVSHIPS letter OOV3M:HCE:sl, 9674, Ser: 52, dated 4 December 1969) and were received on 15 December 1969.

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II. BACKGROUND

NAVSHIPS has provided ARL a well-equipped barge to serve as a pilot facility for the Navy's three TRF's. Each of the TRF's has transducer test facilities equipped with the AN/FQM-10(V) Sonar Test Set, as is ARL's STEP barge (nicknamed for Standardized Transducer Evaluation Program).

One of the uses envisioned for the STEP barge was that new types of transducers would be sent to ARL so that baseline measurements could be obtained. From these measurements ARL would be able to recommend meaningful tests for the TRF's to use on the transducer and to provide reasonable test parameters and tolerances.

The first transducer sent to ARL for baseline measurements was the TR-208A, serial BTD-2-69. It did not represent exactly the "new transducer" case because the TR-208A is merely a relatively new design of an existing type of transducer, for which the TRF's already have meaningful test requirements. Test tolerances have been established but not thoroughly checked.

ARL's first objective was to make the "TRF measurements" on the bare transducer to verify existing tolerances or suggest changes in them. These data would also be compared with previous data from the Boston TRF. The second objective was to establish the validity of shipboard single-element impedance measurements by investigating the correlation between such measurements made on the bare transducer and made on the transducer installed in the standard hull-mount dome. The STEP barge is equipped with a standard 360 in. AN/SQS-23 dome.

It was requested by NAVSHIPS that ARL personnel follow this particular transducer and repeat single-element impedance measurements after its installation aboard ship. The purpose of these measurements was to investigate the comparison between shipboard measurements and measurements made in ARL's dome at LTTS, as well as to affirm that the transducer was correctly installed. It is planned that ARL will continue to make similar measurements on this transducer periodically--perhaps each six to twelve months. This procedure of evaluating a new (or relatively new) type of transducer at ARL and then monitoring its performance during its life cycle is one that hopefully will be followed on all types of new transducers in the future. This cradle-to-grave transducer monitoring will enable NAVSHIPS to maintain realistic test tolerances on transducers (both for the TRF's and for shipboard measurements), as well as to monitor transducer performance for the onset of any aging effects or possible failure modes.

III. ARL TEST PROCEDURE

A. Tests Aboard ARL's STEP Barge

ARL received the TR-208A, serial BTD-2-69, on 9 April 1969; it had to be received back at the Boston TRF by 12 May 1969. After allowing time for uncrating/crating, loading/offloading, connecting/disconnecting cables, and reshipment to Boston, the actual test period was 21 April through 5 May 1969.

The test plan for the bare transducer may be summarized as follows:

1. Each of the 432 elements was driven individually, with a 5 kHz 100 V signal; its impedance and source level were measured.
2. Each of the 48 staves of the transducer was driven individually (with the elements in parallel), with a 5 kHz 100 V signal; the source level of the staff was measured. In this same driving configuration, spot checks of the impedance of the individual elements were made.

Item 1 represents the TRF tests on this type of transducer. Item 2 was done to investigate how element impedance shifted as the driving configuration changed and to obtain an additional check of source level uniformity.

With the transducer in the 360 in. dome, the following tests were performed:

3. Individual element impedance measurements were conducted exactly as in item 1; however, no source level measurements were made.
4. Each stave was driven as in item 2 and its source level measured; no impedance measurements were made.

The tests of item 3 were for the previously stated purpose of investigating correlation between individual element impedance measurements with and without the dome. Tests of item 4 were done primarily to compare with the similar source level measurements done in item 2 to see what dome effects existed.

The AN/FQM-10(V) Sonar Test Set was used for all measurements at ARL. A block diagram for the exact setup used in the individual element impedance measurements is shown in Fig. 1(a).

The accuracy of impedance magnitude (Z) measurements with the Pulse Vector Immittance Meter (Scientific-Atlanta Model 1700) is $\pm 2 \Omega$. Its accuracy for impedance phase (ϕ) measurements is ± 2 deg.

B. Shipboard Tests

Tests on the TR-208A, serial BTD-2-69, were conducted aboard the USS VOGELGESANG (DD 862) on 24 - 25 September 1969. The tests consisted of only single element impedance measurements, with each element driven individually with a 5 kHz 100 V signal provided by an external power amplifier (not the shipboard sonar equipment). ARL personnel were greatly assisted by a shipyard mechanic familiar with the installation, who disconnected and reconnected the transducer leads. The short time available was dictated by the ship's schedule for sea trials.

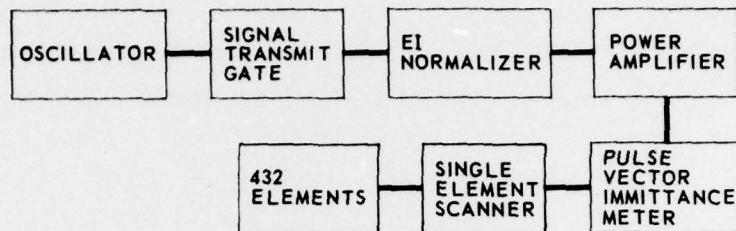


FIGURE 1(a)
MEASUREMENT SYSTEM USING AN/FQM 10(V) AT LAKE TRAVIS

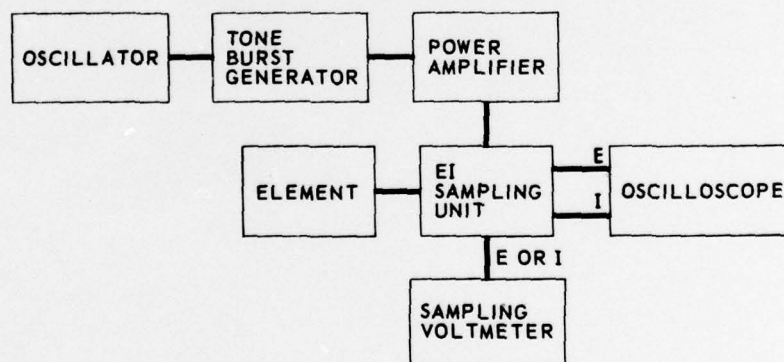


FIGURE 1(b)
MEASUREMENT SYSTEM USED ABOARD USS VOGELGESANG

The block diagram for the test instruments used for the shipboard measurements is shown in Fig. 1(b). A Dranetz model 215 sampling voltmeter was used to measure the voltage and current amplitudes. A dual channel Tektronix type 564 storage oscilloscope was used to measure phase. The external power source for driving individual elements was an ARL-built portable solid state amplifier. The accuracy of this shipboard instrumentation was $\pm 2 \Omega$ for Z and ± 4 deg for ϕ .

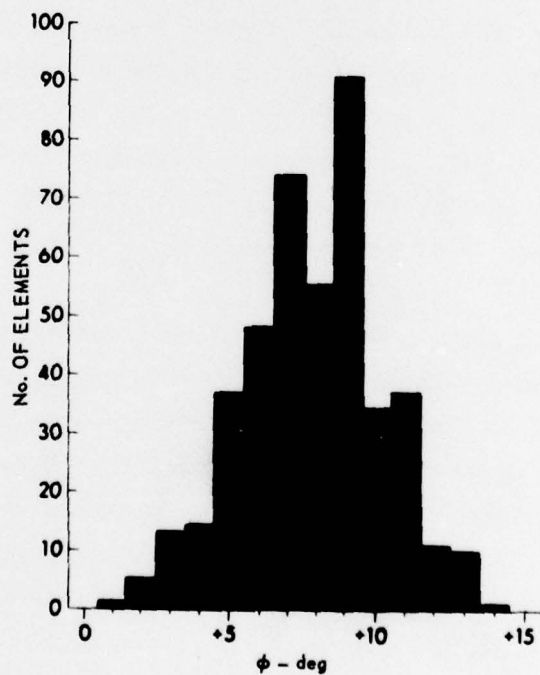
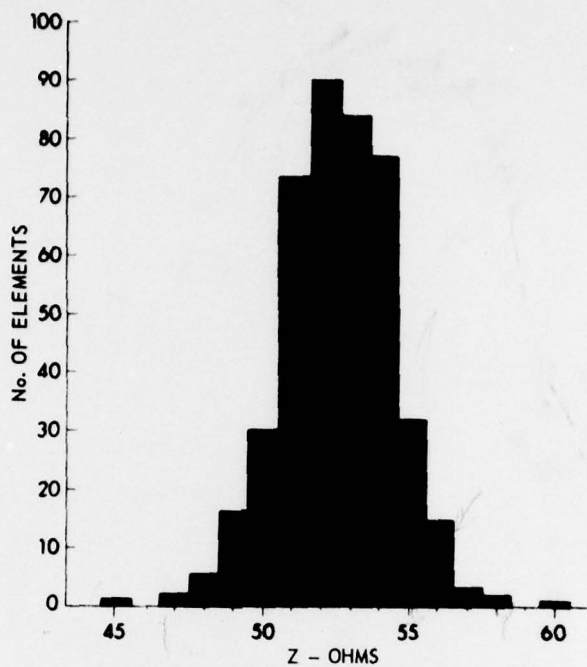
IV. ARL TEST RESULTS

A. Bare Transducer Measurements

The published specifications for the TR-208A that are applicable to the TRF's are taken from NAVSHIPS publication 0967-303-9810. The impedance magnitude of an element at 200 W operating power at 5 kHz is specified to be between 40 and 55 Ω ; the phase should range from -25 deg to +15 deg at the same driving level. Single element source level should be 97.5 \pm 1.0 dB re 1 μ bar at 1 yd.

The results of ARL's single element impedance measurements (each element driven individually) on the bare transducer at LTTS are shown in Fig. 2. It can be seen that all elements met the phase specification; however, 35 elements lay outside the acceptable Z range. All but one of these lay in the range 55 - 58 Ω . These out-of-tolerance elements represent 7% of the transducer.

As stated in Section III, each element was driven individually with a 100 V signal, not at precisely 200 W as the source level specification calls for. The actual driving power levels varied from 165 to 222 W, a range of approximately 1.3 dB. Based upon these driving levels, corrections were made to measured source level values to simulate the 200 W drive level. After these corrections were made, there remained 84 elements that did not fall within the 96.5 - 98.5 dB range; however, only 5 of these fell below 95.5 dB.



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FIGURE 2
HISTOGRAMS OF Z AND ϕ OF BARE TRANSDUCER AT 5.0 kHz

The mean value of the uncorrected measured source level values was 96.3 dB; by making a correction to compensate for the average driving power of 189 W, the corrected mean source level was 96.6 dB, a passing value.

It can be noted from Fig. 2 that the spread of Z and ϕ values was not great, a very favorable characteristic for such a transducer array. Likewise, even the uncorrected source level values varied only from 94.6 dB to 97.7 dB.

When staves of the transducer were driven, source level again was quite uniform for the transducer array. Values of stave source level (for which there was no means of correcting each stave to identically the same driving power) varied only from 112.0 to 114.8 dB. Of these values, 46 of the 48 lay between 114.0 and 115.3 dB; the mean value of stave source level was 114.8 dB.

The spot checks of element impedance measured while staves of the transducer (9 elements) were driven revealed significant shifts in complex impedance of a given element between the condition of it being driven alone versus being driven in parallel with its neighbors. This effect, due to element interaction, has been postulated and observed many times previously. On this particular transducer the shift both in Z and in ϕ is demonstrated by the typical values shown in Table I. It can readily be appreciated that shifts in Z of the order of 5Ω could cause one to reject good elements if one measured element impedance while driving an entire stave. The values of Table I certainly indicate that two sets of element impedance data are not equivalent and thus cannot be compared unless the driving configurations are equivalent.

TABLE I

<u>ELEMENT NUMBER</u>	<u>SHIFT IN Z</u>	<u>SHIFT IN ϕ</u>
1 (TOP)	-0.7 Ω	-9 deg
2	-4.7 Ω	-15 deg
3	-5.6 Ω	-16 deg
4	-4.0 Ω	-16 deg
5	-3.9 Ω	-16 deg
6	-4.0 Ω	-15 deg
7	-3.5 Ω	-16 deg
8	-5.7 Ω	-15 deg
9 (BOTTOM)	-0.8 Ω	-8 deg

B. Measurements in the Dome

Figure 3 contains histogram plots of Z and ϕ measured with the transducer in the dome. No significant variations were noted between element measurements in the dome and out of the dome. The average value of Z in the dome was 52.2 Ω , as compared with 52.4 Ω for the bare transducer. Mean values of ϕ were 8.4 deg and 8.2 deg, respectively. Although mean values did not shift appreciably, a change in shape of the histograms can be observed. The distribution of values is somewhat broader with the transducer in the dome. The reason for this effect is not known. Particular attention was paid to impedance measurements on elements at a relative bearing of 180 deg. These elements look directly at the baffle in the after portion of the dome. No effects due to reflections from the baffle were noted.

On the contrary, the stove source level measurements made in the dome do show evidence of dome effects. Although without beam-forming circuitry it is very difficult to measure meaningful values of dome transmission loss, it is estimated that dome transmission loss is from 0.5 to 1.0 dB, based upon examination of stove source

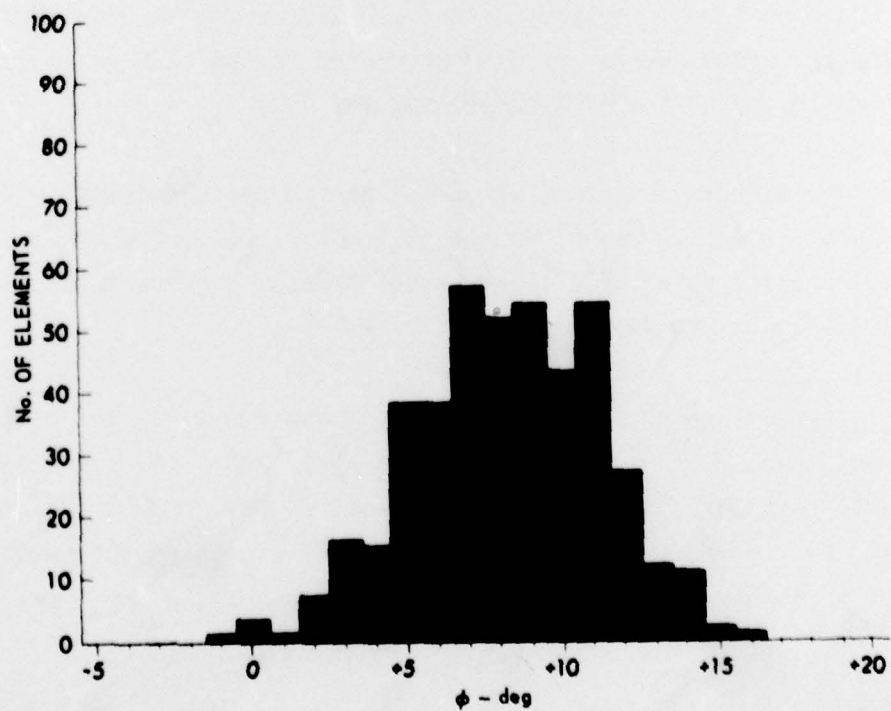
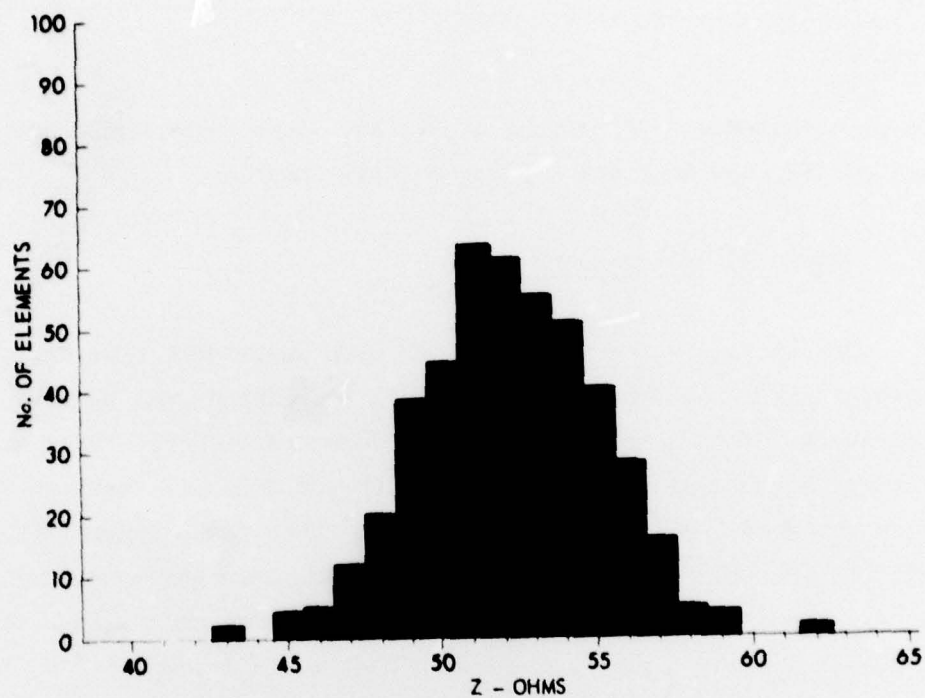


FIGURE 3
HISTOGRAMS OF Z AND ϕ OF TRANSDUCER IN DOME AT 5.0 kHz

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level measurements for groups of staves. This value would be applicable at 000 deg, 090 deg, and 270 deg relative bearing.

C. Shipboard Measurements

The average value of Z obtained when individual transducer elements were measured aboard the USS VOGELGESANG was 50.1 Ω . The average value of Z measured in ARL's dome was 52.2 Ω . Phase values aboard the ship averaged 7.9 deg, which compared well with an 8.4 deg mean value of ϕ measured in ARL's dome. This phase comparison is much better than one would expect with the basic phase measuring accuracies involved. The 2 Ω difference between mean values of Z at LTTS and aboard ship is more nearly what would be expected with two entirely different schemes of measurement, both with $\pm 2 \Omega$ accuracy. An additional contribution to this 2 Ω difference between LTTS and shipboard measurements could be accounted for by 61°F water temperature at Boston versus the LTTS temperature of 67°F.

One defective element was noted during the shipboard measurements; element 2 of stave 26 was an open circuit. This failure is probably accounted for by a cable or connector problem because this element performed well at ARL.

Figure 4 shows a histogram plot of the impedance values measured aboard ship. The spread of values is again noted to be favorably small. Although ARL's dome measurements at LTTS show a greater spread with the transducer in the dome than bare, the shipboard measurements show a smaller spread than the LTTS measurements in the dome.

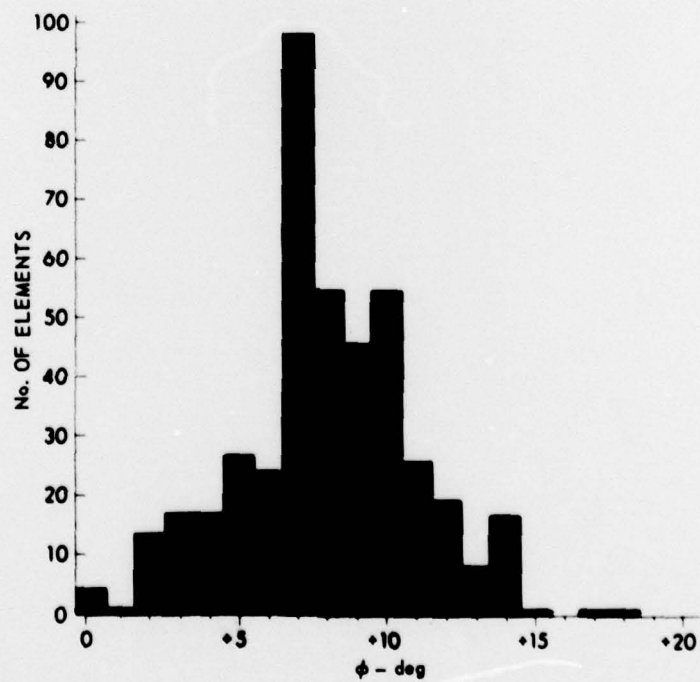
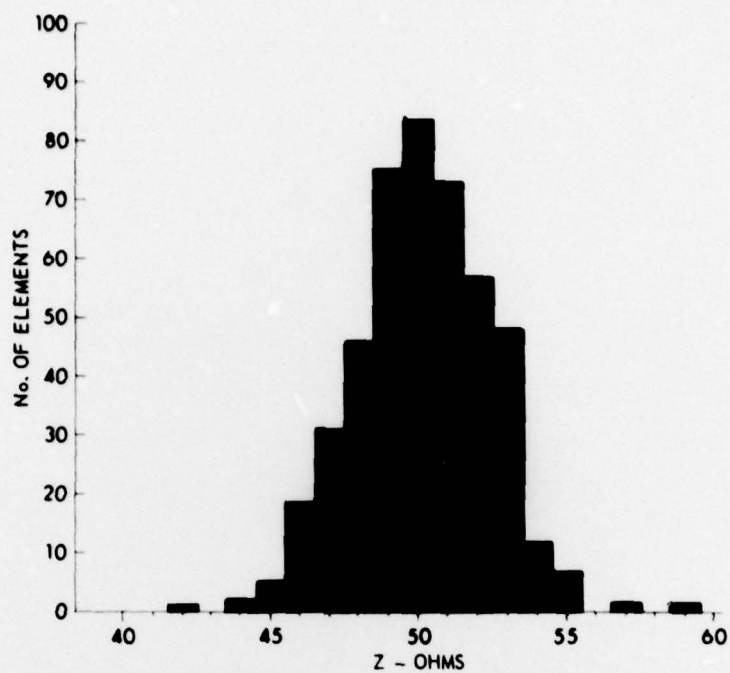


FIGURE 4
HISTOGRAMS OF Z AND ϕ OF TRANSDUCER
AT 5.0 kHz ABOARD USS VOGELGESANG

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V. COMPARISON OF RESULTS WITH PREVIOUS TESTS AT THE BOSTON TRF

Tests on the TR-208A, serial BTD-2-69, were conducted at the Boston TRF in March 1969, just prior to its shipment to ARL. Unfortunately, due to administrative problems these data were not received at ARL until 15 December 1969. In retrospect, it is unfortunate that this technical memorandum was delayed pending receipt of the Boston data, because examination of the data revealed that they are not comparable with ARL's measurements. There are two reasons the data are not comparable -- (1) the data were measured prior to installation of the AN/FQM-10(V), and thus were measured by using only an oscilloscope for E, I, and ϕ measurements; and (2) the transducer was driven with a set of AN/SQS-23 drivers and probably was driven stavewise. If entire staves of the transducer were driven as the elements were measured, the data would be greatly affected by the shifts in Z and ϕ values shown in Table I of Section IV. The use of the oscilloscope method for these measurements results in accuracy much poorer than that of the AN/FQM-10(V).

Because it was evident from examination that these data would not be comparable with ARL's data, only a cursory analysis was performed. This analysis bears out the poor comparison expected. For example, on 195 of the 432 elements (45%), Boston data and ARL data differ by 10 Ω or more. It was also noted that 48 elements (11%) show Z values from Boston less than 40 Ω , which is the published lower limit on Z. The very poor comparison between ARL data and Boston data is again pointed out by the fact that ARL's data (as described in Section IV.A.) show 30 elements to be out of specification--but with high Z values rather than low ones.

VI. SUMMARY AND CONCLUSIONS

A. Baseline Measurements

With regard to ARL's measurement of baseline data on the bare transducer, several conclusions can be drawn. This transducer failed the present TRF tests--119 of the 432 elements (27.5%) failed one of the tests. Thirty-five elements showed impedance magnitude (Z) values that were too high (greater than 55 Ω). Eighty-four elements showed source level values that were too low (less than 96.5 dB). It is interesting to note that there is no overlap between these groups of elements; those with high impedance all showed good source level values. Two conclusions can be drawn. If one wishes to accept this particular transducer, consideration should be given to raising the upper limit of Z and lowering the lower limit on source level. The upper limit on Z should be increased to perhaps 60 Ω while the lower limit on source level should be decreased to perhaps 95.5 dB. Raising the lower limit on Z was investigated because several elements with low source level showed relatively low Z values (45 - 48 Ω). No conclusion was reached because several low Z elements checked good on source level. It is interesting to note that no elements of this transducer fell in the acceptable range from 40 to 45 Ω or the acceptable ϕ range -25° to 0° . Perhaps this indicates that these lower limits should be raised. NUSL (Code 2230.1), who is charged with the responsibility of maintaining up-to-date TRF transducer test specifications, was made aware of these results before preparation of this memorandum.

As stated previously, the suggestions to raise the Z limit and lower the source level limit are based solely upon the desire to accept the TR-208A, serial BTD-2-69. Because this transducer was installed aboard ship and subsequently passed required sonar certification tests, it is assumed that one should accept this transducer. However, it is understood that shipboard system source level measurements, though acceptable, were below average for this system. This information corroborates ARL's low values of source level measured on many elements.

No attempt was made to compare ARL's measurements in detail with those data forwarded from the Boston TRF. Boston measured no source level values to be compared with ARL's values; the impedance data are not comparable for the several reasons stated in Section V. Boston's data show that 48 elements were out of specification with Z values too low when the transducer left the TRF. It is surprising that the transducer was shipped to ARL in this condition. However, ARL's Z data indicate no elements with values too low. The attempted comparison of ARL's data with the Boston TRF data simply serves to point out the tremendous increase in capabilities afforded by the AN/FQM-10(V) Sonar Test Set. This system allows more accurate measurements of impedance, driving only one element at a time, and allows simultaneous measurement of single element source level. The importance of the source level measurements cannot be overestimated, based upon ARL's measurements on this transducer. No meaningful correlation existed between those elements that failed the source level test and their impedance values. Source level must be measured.

Another conclusion reached, after all of the manipulations and corrections involved in checking source level data, is that TRF source level specifications should be in terms of voltage drive rather than power. The AN/FQM-10(V) can normalize voltage (and current)

expediently but not power. It also would appear that voltage is a more meaningful parameter with the AN/SQS-23 system because the drivers are adjusted for a particular voltage output.

B. Shipboard Impedance Measurements

The comparison between all of the single element impedance values (LTTS without dome, LTTS with dome, and shipboard) is a highly favorable indication for the widespread application of this type of measurement for shipboard transducer testing. It was hoped that individual element impedance measurements aboard ship in the presence of a dome would prove to correlate in a meaningful fashion with such measurements made on the bare transducer. Individual element impedance measurements on bare transducers have proved to be very effective at revealing failure modes in the transducer elements. The fact that measurements with and without domes are identical to within the accuracy of measurement represents certainly the most favorable correlation that could have been obtained. It should be emphasized that this favorable comparison between shipboard and TRF-type impedance measurements is based strictly upon equivalent driving configurations. ARL's measurements aboard ship were made while driving each element individually. Had similar impedance measurements been made while using shipboard drivers to power an entire stave at one time, the resulting data would certainly not have compared favorably with the bare transducer measurements. The shifts in impedance shown in Table I of Section IV would have prevented a favorable comparison.

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